THE AMBIENT DUST STUDY AT LUBBOCK LAKE LANDMARK

by
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Abstract

The Southern High Plains of the United States has a long history of dust storms. The worst dust storms occurred during the infamous "Dust Bowl" of the 1930's Since then, improved farming techniques and other improvements in land management have helped reduce airborne dust levels. However, it is hard to say exactly how much the situation has improved without accurate measurements of dust levels. If we are to judge properly the effectiveness of changing land use practices, we must establish an accurate and long term record of past and present dust levels. The Lubbock Lake Ambient Dust Project was initiated to begin such a record. This paper describes the field site, explains measurement techniques, and reports preliminary findings following four months of data collection at Lubbock Lake Landmark State Historical Park in Lubbock, Texas.

Introduction

Most would agree that the frequency and intensity of dust storms have lessened and the overall air quality within the Southern High Plains has improved since the "Dust Bowl" years of the 1930's. However, it is hard to say exactly how much the situation has improved. It is difficult to quantify air quality improvements provided by better land management practices and improved farming methods without an accurate and long-term record of ambient dust levels.

Visibility records, provided by the National Weather Service, can provide an adequate surrogate for dust concentration measurements (Pollard, 1977; Lee *et al.* 1993; Ervin & Lee 1994; Lee *et al.* 1994; Lee & Tchakerian 1995; Peterson & Gregory, 1993; Bernier, 1995). These studies have provided important information about past dust levels and the effects of land management practices and climatic factors. Such studies, however, rely heavily on the conversion of visibility distance to mass concentration of dust. Future studies could be strengthened by an accurate record of direct dust concentration measurements.

Currently, the Texas Natural Resource Conservation Commission (TNRCC) is monitoring dust concentrations in Lubbock, Texas for regulatory purposes. Unfortunately, TNRCC obtains dust samples every other day so they do not obtain a continuous record of dust concentrations (Bryan Lambeth, TNRCC, personal communication).

If we are properly to judge the effectiveness of changing land use practices, we must establish an accurate and long term record of past and present dust levels. The Lubbock Lake Ambient Dust Project has begun such a record. We intend to obtain a continuous record of dust concentrations to establish typical dust values for this part of the Southern High Plains. We intend to track dust levels for many years to establish normal background levels, typical peak values, and general trends in ambient dust concentrations. Another goal is to define the relationship between dust levels and meteorological factors such as wind speed, wind direction, and relative humidity.

PM_{10} Defined

Dust levels are often reported as concentrations of PM_{10}, where PM_{10} is particulate matter with a mass median aerodynamic diameter less than 10 micrometers (Federal Register, 1987a). PM_{10} is one of the seven air pollutants regulated under the National Ambient Air

Quality Standards (NAAQS). Of the seven NAAQS regulated pollutants, PM_{10} is the only one that is chemically nonspecific. Concentrations of PM_{10} are expressed as the mass of particulate matter in a cubic meter of air. The current EPA standard for PM_{10} is composed of both a 24-hour allowable average and an annual allowable average. To be considered in compliance with Federal regulations, the daily average concentration should not exceed 150 micrograms per cubic meter of air ($\mu g/m^3$) more than three times in three years and the annual average should not exceed 50 $\mu g/m^3$ (Federal Register, 1987b).

Since PM_{10} is particulate matter that is very small and remains suspended in the air for long periods, it is easily inhaled deep into the lung. Increased death (mortality) and diseases (morbidity) have been linked to periods of high PM_{10} concentrations (USEPA, 1986). In the Southern High Plains of West Texas, soil dust grains constitute most PM_{10} particles.

Field Site and Experimental Methods

Site selection is an important aspect of any field experiment and it is especially important when choosing a long-term monitoring site. Ideally, one would prefer a natural site that will not change significantly through time although land use of the surrounding region may be in a state of flux. Lubbock Lake Landmark State Historical Park, protected by state and national preservation directives, provides such an "island of stability."

The north side of this 1.5 km^2 park was chosen for the monitoring site. This portion of the park has been restored to its natural semiarid grassland condition and will remain in a natural state for the foreseeable future. The grassland site is well exposed and contains no obstructions such as buildings or trees to complicate airflow patterns. The grasslands within the park form a buffer zone between the monitoring site and active sources of dust. In addition, the site is in the sparsely populated extreme north part of the city of Lubbock (N33° 38' 07" W101° 53' 33") and it is far from busy streets or large industrial sources of particulate matter.

Meteorological/Sampling Tower

A meteorological/sampling tower was erected at the Lubbock Lake grassland site, as shown in Fig.1. The two-meter tower is equipped with a cup anemometer, a wind vane, a temperature probe, a relative humidity sensor, three PM_{10} samplers, and a portable data acquisition system. The data acquisition system records meteorological data and simultaneously controls the dust samplers by switching them on or off at midnight. The whole system is powered by a 12-volt car battery connected to a solar panel which can transform 1000 W/m^2 of solar radiation to 18.5 W of usable power.

Dust samples (PM_{10}) are acquired by drawing ambient air through polycarbonate membrane filters using a constant flow, double acting, diaphragm pump. The battery powered pumps are adjusted for the 1 km altitude so that they draw air at a rate of five liters per minute. The polycarbonate membrane filters are 47 mm in diameter and have a pore size of 0.6 μm.

Filters are dried for 24 hours then weighed before being placed into the sampler. Each sampler is turned on at midnight and collects PM_{10} for 24 hours. Filters are then removed from the sampler and again dried in a dehumidifier for 24 hours before the sample mass is measured. We typically collect around 0.4 mg of dust in 24 hours during intense storms and around 0.1 mg during clear periods. The sample mass is divided by the total volume of air that passed through the filter in 24 hours and the result is reported in units of micrograms per cubic meter.

Results and Discussion

The tower was completed and we began recording meteorological data on 19 March 1996. Dust sampling began on 23 March 1996 and we have maintained a nearly continuous record from this date[1]. Data collected from 23 March 1996 to 31 July 1996 appear in Table 1. The columns contain the 24-hour average wind speed, wind direction, and PM_{10} concentration. Wind speed and PM_{10} concentration are plotted as functions of time in Figs. 2 and 3, respectively.

Mean and Standard Deviation of PM_{10} Values

From 23 March to 31 July, the arithmetic mean of the measured PM_{10} concentrations, $\underline{c}$, was 26.6 $\mu g/m^3$ and the standard deviation of the PM_{10} concentration, σ_c, was 20.2 $\mu g/m^3$. A measure of the relative variability of measured PM_{10} values is provided by the dimensionless ratio $\sigma_c/\underline{c}$, which is equal here to 0.76. Such a large number suggests that average PM_{10} concentration fluctuations about the mean are nearly as large as the mean concentration.

As shown in Figure 3, PM_{10} values hover near or below the mean concentration for most of the time. Dust events appear as intermittent peaks that dramatically thrust upward from ambient background values. Most of the large concentration peaks occurred during March, April and May whereas June and July had only one PM_{10} value above 50 $\mu g/m^3$. It follows that average PM_{10} values were higher in April and May than in June and July. Monthly averages were 32 $\mu g/m^3$ in April , 28 $\mu g/m^3$ in May, 20 $\mu g/m^3$ in June, and 21 $\mu g/m^3$ in July[2]. As shown in Fig. 2, winds were strongest in April and May and weaker in June and July. Strong winds in the late winter and spring are often associated with frontal passage which may produce strong winds that last for many hours whereas strong winds in the summer months are often associated with thunderstorm outflows which last for shorter periods (Bernier, 1995). Soil surface conditions also play an important role in reducing PM_{10} values (Lee *et al.*, 1994). By June, crops are normally established in previously bare agricultural fields and individual plants have grown sufficiently to shelter the soil surface.

PM_{10} Extremes

The maximum PM_{10} value of 166.0 $\mu g/m^3$ was measured on 13 April whereas the minimum value of 8.8 $\mu g/m^3$ was measured six days earlier on 7 April. Other extreme values appear to occur less than one week apart. For example, the second highest value of 116.8 $\mu g/m^3$ occurred on 24 March, just seven days before the second lowest value of 10.6 $\mu g/m^3$ which occurred on 31 March. An extreme low of 11.8 $\mu g/m^3$ occurred on 22 May while an extreme high of 80.0 $\mu g/m^3$ occurred on 26 May, a separation of only four days. It appears that PM_{10} extremes are often spaced closely together.

Distribution of PM_{10} Values

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[1] Meteorological data have been recorded without interruption but two PM_{10} values were lost due to equipment failure. Gaps in the data set were filled by using PM_{10} values provided by TNRCC.

[2] The monthly average for March was not included since a full month of PM_{10} values was not measured.

As shown in Fig. 3, positive fluctuations above the mean are generally much larger than negative fluctuations that fall below the mean. This suggests a skewed distribution. One method of quantifying the skewness of a distribution is to calculate the skewness factor (Batchelor, 1953) defined as

$$S_k = \frac{\overline{(c - \bar{c})^3}}{\sigma_c^3}$$

where the PM_{10} concentration is denoted here by lowercase *c*. The skewness factor for a Gaussian or normal distribution is zero. For the Lubbock Lake PM_{10} data, a positive value of S_k=3.8 reveals that the distribution of daily PM_{10} values is positively skewed.

Another sensitive test of the PM_{10} time series is obtained by calculating the flatness factor or kurtosis defined as

$$K = \frac{\overline{(c - \bar{c})^4}}{\sigma_c^4}$$

A normal distribution has a flatness factor equal to three and values much greater than three suggest an intermittent process (Townsend, 1976). For the Lubbock Lake PM_{10} data, an abnormally large value of K=22.2 suggests that most of the atmospheric dust in the Southern High Plains is generated by intermittent pulses of intense dust storm activity.

The probability density distribution of the daily PM_{10} values was calculated as

$$p(c) = \frac{Prob.\left[c - \frac{\Delta c}{2} < c < c + \frac{\Delta c}{2}\right]}{\Delta c} = \frac{1}{\Delta c}\frac{N_c}{N}$$

where N is the total number of observations, N_c is the number of observations falling between the values c-Δc/2 and c+Δc/2. Here we used an increment of Δc = 10 $\mu g/m^3$. The resulting probability density distribution is shown in Fig. 4.

Figure 4 shows clearly the positive skewness of the distribution. The dashed line in Fig. 4 marks the mean value of 26.6 $\mu g/m^3$ whereas the mode of the distribution is around 17 $\mu g/m^3$. A smaller secondary mode is found around 65 $\mu g/m^3$; these values occurred primarily during March and April when intense dust storms were more frequent. There is an apparent low probability of moderate PM_{10} values around 50 $\mu g/m^3$. This result agrees with Lee & Tchakerian (1995) who conclude that "moderate events contribute little to the total dust amounts" in the Southern High Plains.

Conclusions

Lubbock Lake Landmark is an ideal spot for studying ambient dust levels in the Southern High Plains. This grassland site provides a stable experimental site for a long term dust monitoring experiment. A continuous record of PM_{10} measurements has been obtained since 23 March 1996 and the site continues to operate today. Studies like this one provide valuable information that allows a proper assessment of changing land management practices on ambient dust levels.

The probability density distribution was calculated for all PM_{10} values measured at Lubbock Lake from 23 March to 31 July 1996. The distribution was positively skewed with a mode of 17 $\mu g/m^3$, a mean of 26.6 $\mu g/m^3$, a standard deviation of 20.2 $\mu g/m^3$, a skewness factor of 3.8 and a flatness factor of 22.2. We find that PM_{10} concentrations are normally around 10 to 30 $\mu g/m^3$ and that higher PM_{10} values are generated by relatively short duration dust storms that occur intermittently. Extremely high values and extremely low values of PM_{10} were often found to occur only a few days to less than one week apart.

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